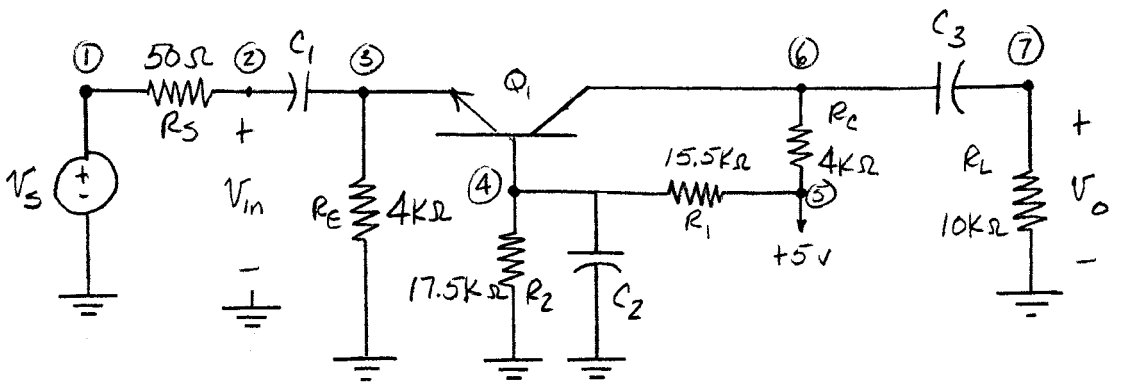
ECE 302 - HW #11 - SOLUTION - 30 PTS

A)

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Common-Base Amplifier
VCC 5 0 5
R1 5 4 15.5K
R2 4 0 17.5K
RC 5 6 4K
RE 3 0 4K
RS 1 2 50
RL 7 0 10K
C1 2 3 47U
C2 6 7 47U
CE 4 0 47U
VS 1 0 AC 1M
Q1 6 4 3 Q2N3904
.model Q2N3904 NPN(Is=6.734f Xti=3 Eg=1.11 Vaf=74.03
+ Bf=416.4 Ne=1.259 Ise=6.734f Ikf=66.78m Xtb=1.5
+ Br=.7371 Nc=2 Isc=0 Ikr=0 Rc=1 Cjc=3.638p Mjc=.3085
+ Vjc=.75 Fc=.5 Cje=4.493p Mje=.2593 Vje=.75
+ Tr=239.5n Tf=301.2p Itf=.4 Vtf=4 Xtf=2 Rb=10
.AC DEC 25 1 100MEG
.OP
.PROBE
.END
```

- .OP

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**** BIPOLAR JUNCTION TRANSISTORS


NAME            Q1
MODEL           Q2N3904
IB              4.03E-06
IC              4.89E-04
VBE             6.47E-01
VBC            -4.26E-01
VCE             1.07E+00
BETADC          1.21E+02
GM              1.88E-02
RPI             7.51E+03
RX              1.00E+01
RO              1.52E+05
CBE             1.20E-11
CBC             3.17E-12
CJS             0.00E+00
BETAAC          1.41E+02
CBX/CBX2        0.00E+00
FT/FT2          1.96E+08
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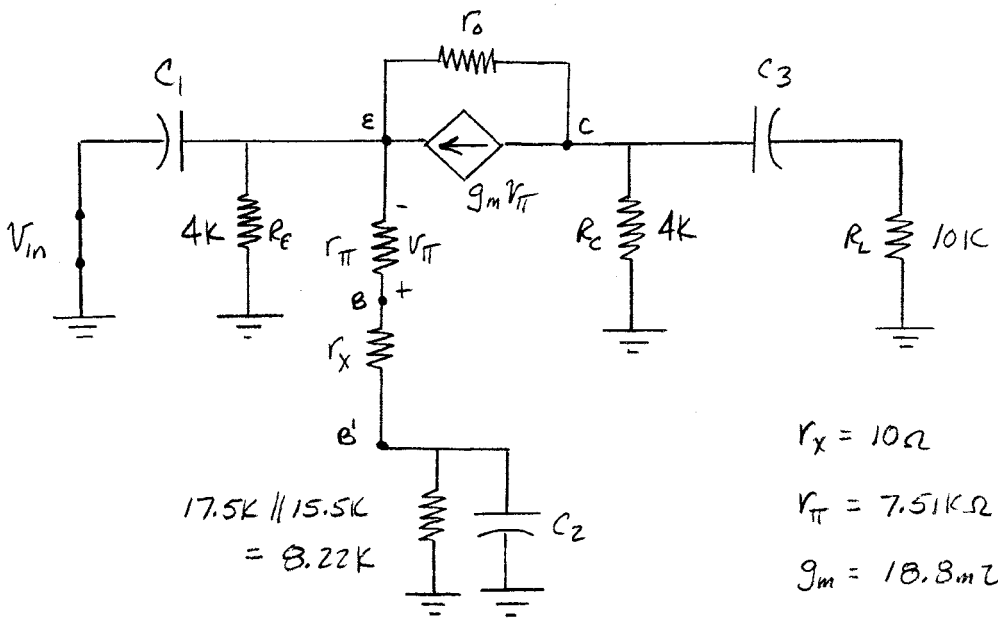
B) LOW FREQ. MODEL WITH V_{in} SHORTED (IGNORE R_c)



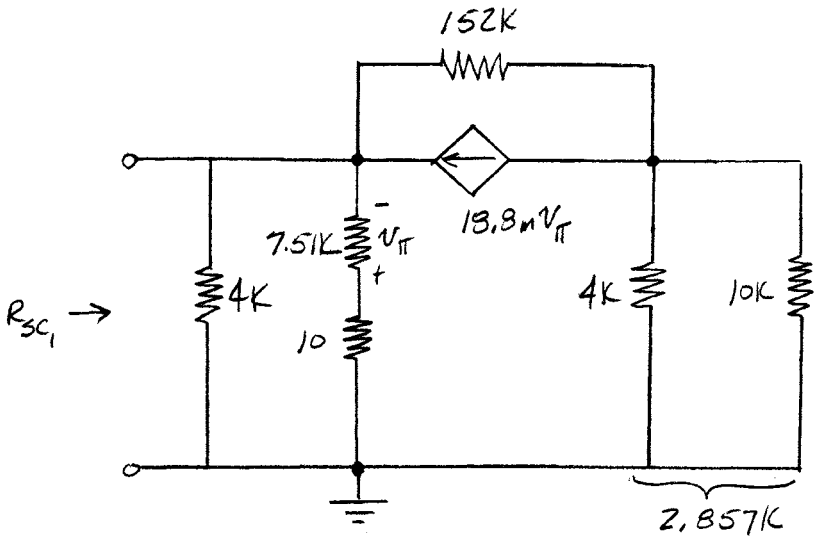
$r_x = 10\Omega$

$r_\pi = 7.51K\Omega$

$g_m = 18.8m\,\mho$

$r_o = 152K\Omega$

1) $\uparrow_{SC_1}$ (SHORT C_2, C_3)



- DOING A SOURCE TRANSFORMATION

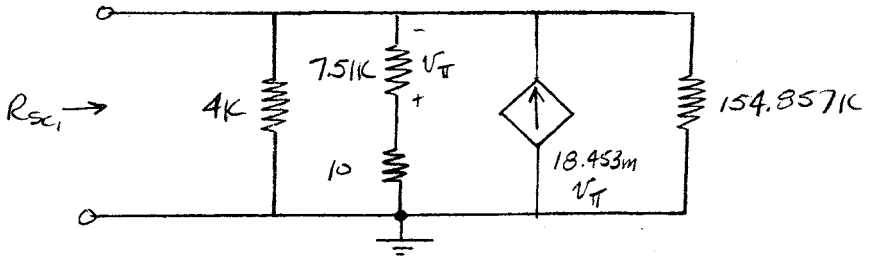
$$V = (18.8m\ V_\pi)\ 152K = 2.8576K\ V_\pi$$

$$R_{EQ} = 152K + 2.857K = 154.857K$$

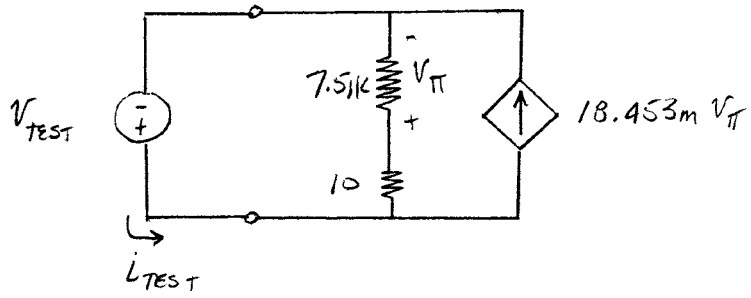
- TRANSFORMING AGAIN

$$i = (2.8576K\ V_\pi) / 154.857K = 18.453m\ V_\pi$$

– RESULTING CIRCUIT



$$4K \parallel 154.857K = 3.9K$$



$$i_{TEST} = 18.453m\, V_\pi + \frac{V_\pi}{7.51K}$$

$$= 18.586m\, V_\pi$$

$$V_\pi = V_{TEST}\ \frac{7.51K}{7.51K+10} = 0.9987\, V_{TEST}$$

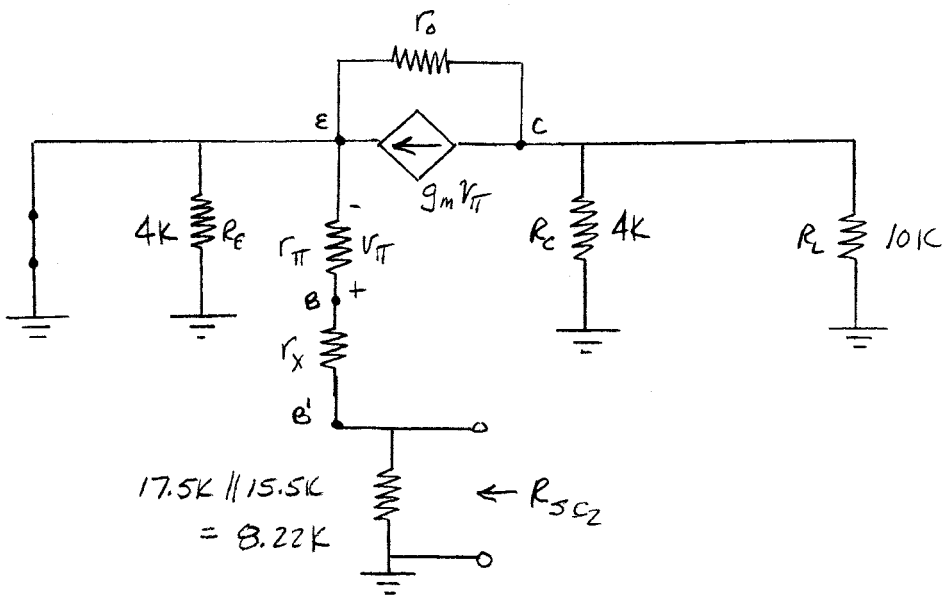
$$\therefore\quad i_{TEST} = 18.586m(0.9987)V_{TEST}$$

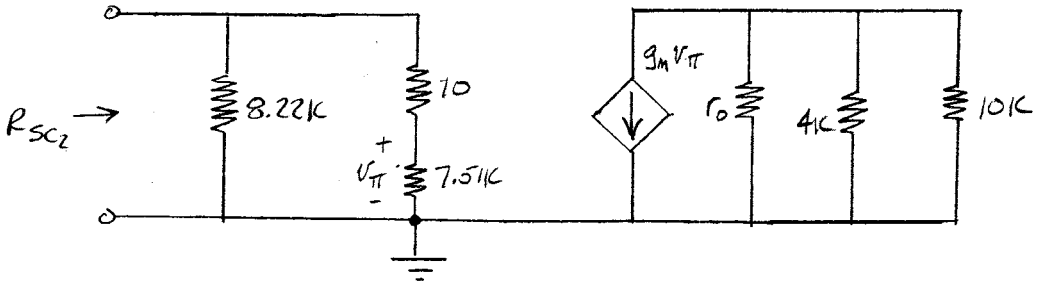
$$\frac{V_{TEST}}{i_{TEST}} = \frac{1}{18.586m(0.9987)} = 53.87\Omega$$

$$\therefore\quad R_{SC_1} = 3.9K \parallel 53.87 = 53.1\Omega$$

$$\tau_{SC_1} = (53.1)\,C_1$$

2) τ_{sc_2} (SHORT C_1, C_3)

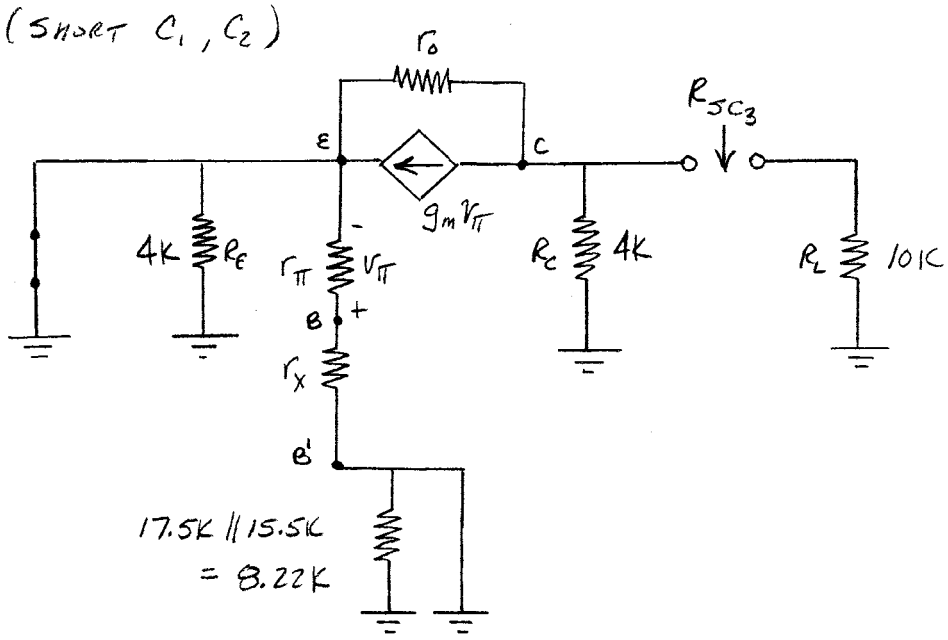


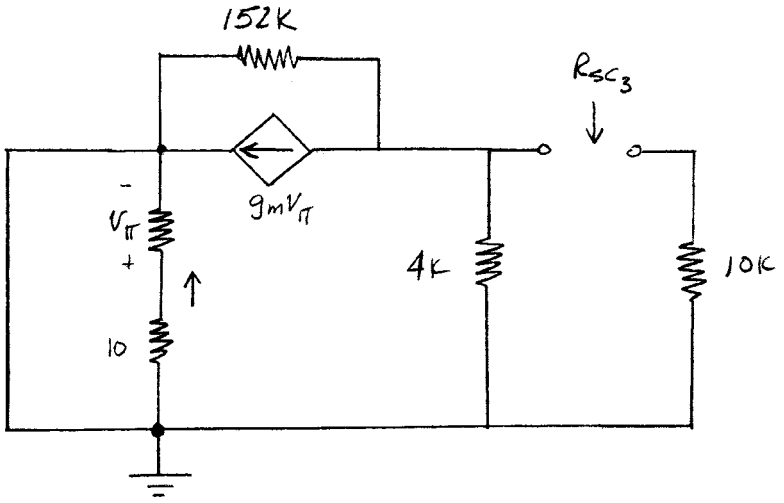


$$R_{sc_2} = 8.22K \parallel 7.52K = 3.927K\Omega$$

$$\tau_{sc_2} = (3.927K)\,C_2$$

3) τ_{sc_3} (SHORT C_1, C_2)





SINCE $10\left(\frac{V_\pi}{r_\pi}\right) + V_\pi = 0$ THEN $V_\pi = 0$

$\therefore \; R_{SC_3} = 152K \| 4K + 10K = 13.897K\Omega$

$\uparrow_{SC_3} = (13.897K)\,C_3$

4) $\omega_L = \frac{1}{53.1\,C_1} + \frac{1}{(3.927K)\,C_2} + \frac{1}{(13.897K)\,C_3}$

$= 2\pi(20) = 125.66$

– WE COULD LET $\frac{1}{\uparrow_{SC_1}} = \frac{1}{\uparrow_{SC_2}} = \frac{1}{\uparrow_{SC_3}} = \frac{125.66}{3}$

THEN $\boxed{C_1 = 450\mu F, \quad C_2 = 6.08\mu F, \quad C_3 = 1.72\mu F}$

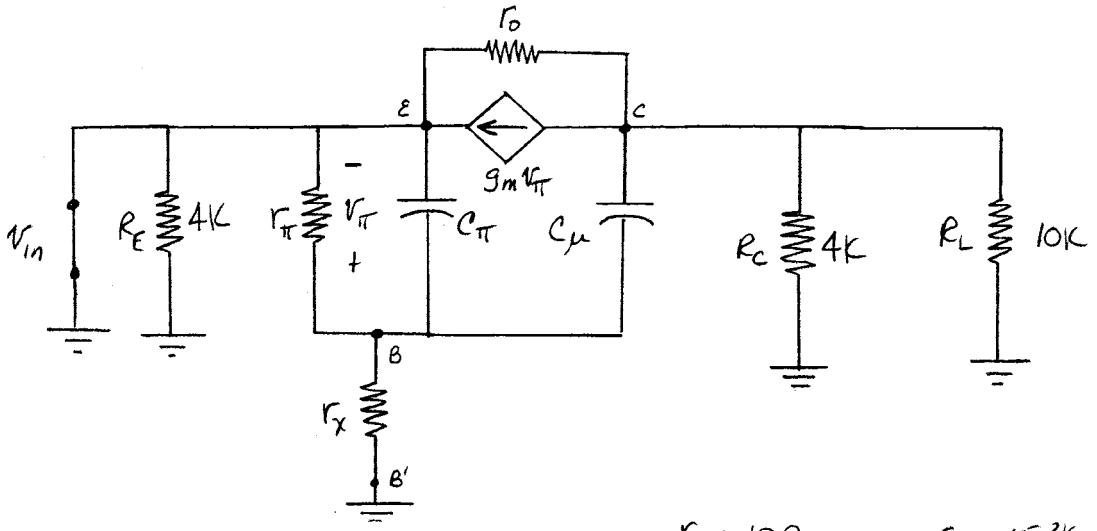
OR WE COULD LOWER C_1 (SEE S10.5) WITH LETTING

$\frac{1}{\uparrow_{SC_1}} = 0.9\,\omega_L = 113.09 \Rightarrow C_1 = \frac{1}{(53.1)(113.09)} = \boxed{166.5\mu F}$

$\frac{1}{\uparrow_{SC_2}} = 0.05\,\omega_L = 6.283 \Rightarrow C_2 = \frac{1}{(3.927K)(6.283)} = \boxed{40.5\mu F}$

$\frac{1}{\uparrow_{SC_3}} = 0.05\,\omega_L = 6.283 \Rightarrow C_3 = \frac{1}{(13.897K)(6.283)} = \boxed{11.5\mu F}$

C) HIGH FREQ. MODEL WITH V_{in} SHORTED (IGNORE R_c)

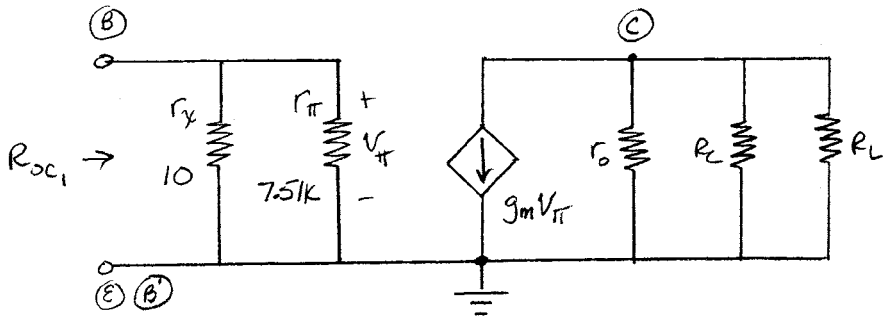


$r_x = 10\Omega$ $\quad r_o = 152K$

$r_\pi = 7.51K\Omega$ $\quad C_\pi = 12pF$

$g_m = 18.8mU$ $\quad C_\mu = 3.17pF$

1) $\uparrow_{OC_1}$ (OPEN C_μ)

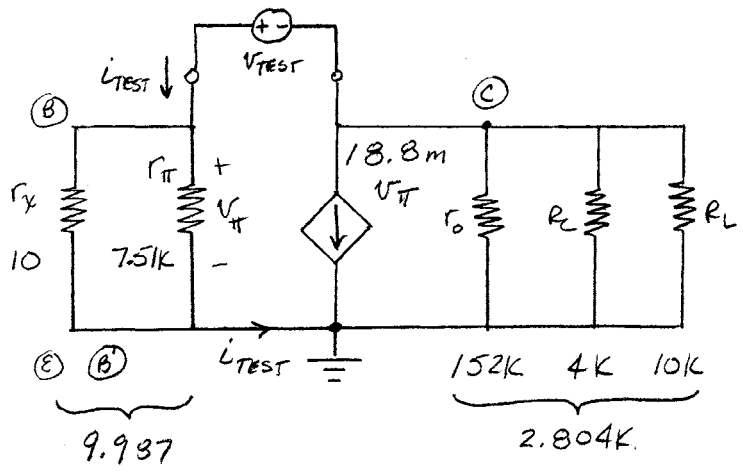


$$R_{OC_1} = 10 \| 7.51K = 9.987\Omega$$

$$\uparrow_{OC_1} = C_\pi R_{OC_1} = (12p)(9.987)$$

$$= 119.84 \text{ psec}$$

2) τ_{OC_2} (OPEN C_π)



$$v_{TEST} = i_{TEST}(9.987) + 2.804K\,(i_{TEST} + 18.8m\,v_\pi)$$

$$v_\pi = i_{TEST}(9.987)$$

$$\frac{v_{TEST}}{i_{TEST}} = R_{OC_2} = 9.987 + 2.804K\,(1 + 18.8m \cdot 9.987)$$

$$= 3.34K\Omega$$

$$\tau_{OC_2} = C_\mu R_{OC_2} = (3.17p)(3.34K) = 10.59\ n\,SEC$$

3) $$\omega_H = \frac{1}{\tau_{OC_1} + \tau_{OC_2}} = \frac{1}{119.84p + 10.59n}$$

$$= 93.38\ M\,rad/sec$$

$$f_H = \omega_H / 2\pi$$

$$= \boxed{14.86\ MHz}$$

D)

```
CB Amplifier
VCC 5 0 5
R1 5 4 15.5K
R2 4 0 17.5K
RC 5 6 4K
RE 3 0 4K
RS 1 2 50
RL 7 0 10K
C1 2 3 166.5U
C2 6 7 40.5U
CE 4 0 11.5U
VS 1 0 AC 1M
Q1 6 4 3 Q2N3904
.model Q2N3904 NPN(Is=6.734f Xti=3 Eg=1.11 Vaf=74.03
+ Bf=416.4 Ne=1.259 Ise=6.734f Ikf=66.78m Xtb=1.5
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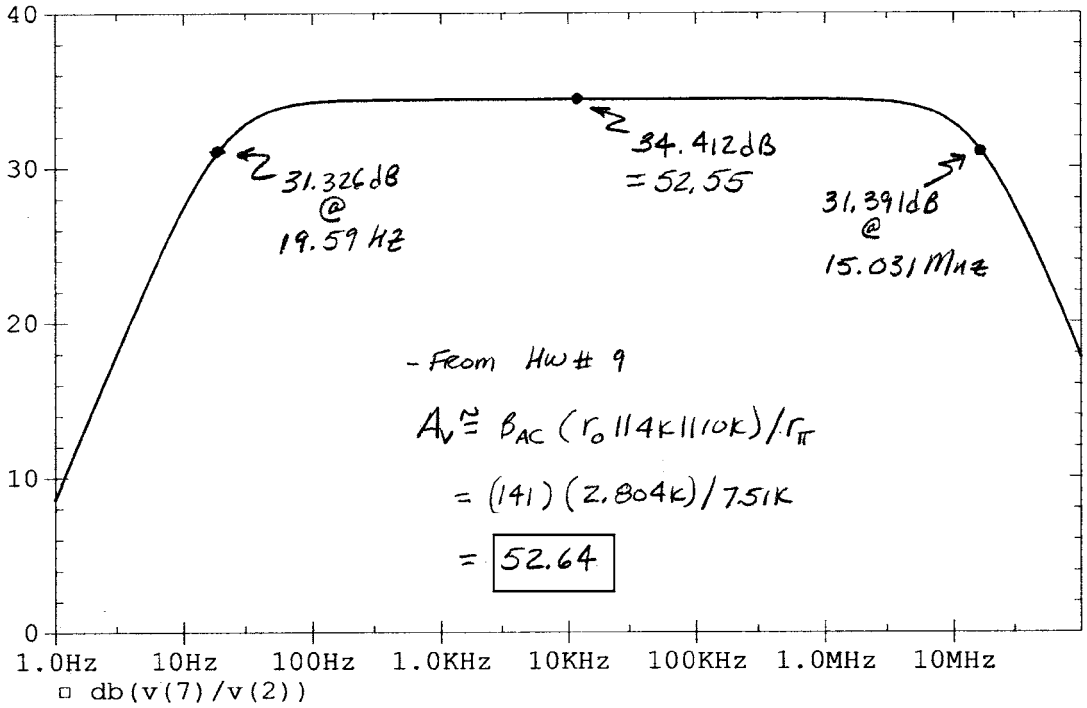
+ Vjc=.75 Fc=.5 Cje=4.493p Mje=.2593 Vje=.75
+ Tr=239.5n Tf=301.2p Itf=.4 Vtf=4 Xtf=2 Rb=10
.AC DEC 25 1 100MEG
.OP
.PROBE
.END
```

CB Amplifier Temperature: 27.0



- From HW # 9

$A_V \cong \beta_{AC} (r_o \| 4K \| 10K) / r_\pi$

$= (141)(2.804K)/7.51K$

$= \boxed{52.64}$

	PSPICE	ESTIMATED	% DIFF
A_V	52.55	52.64	0.171 %
f_L	19.59 Hz	20 Hz	2.01 %
f_H	15.031 MHz	14.86 MHz	-1.14 %